ADVANCED AEROSOL SAMPLING TECHNOLOGIES FOR POINT BIODETECTION

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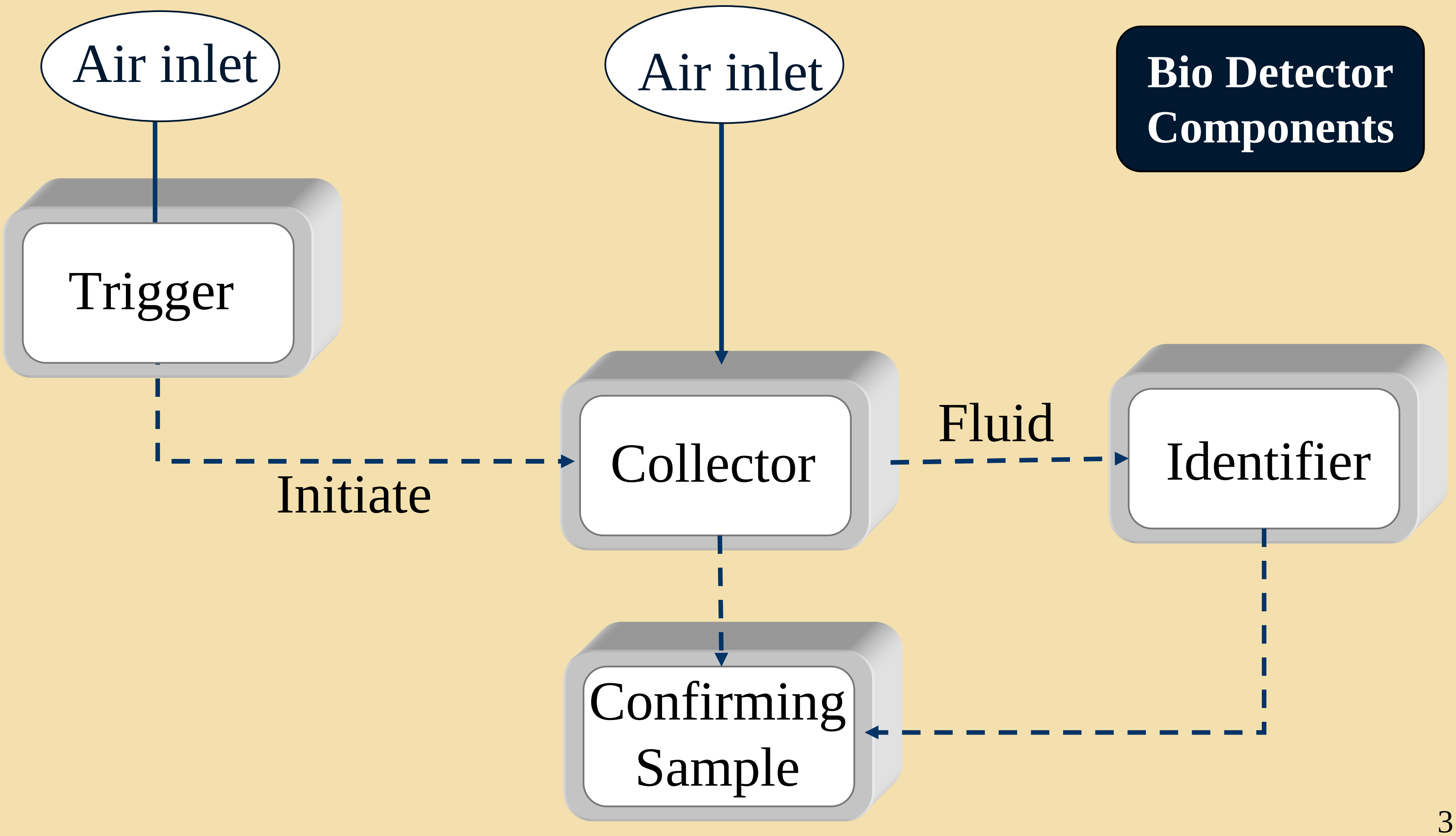
Trigger vs. Collector

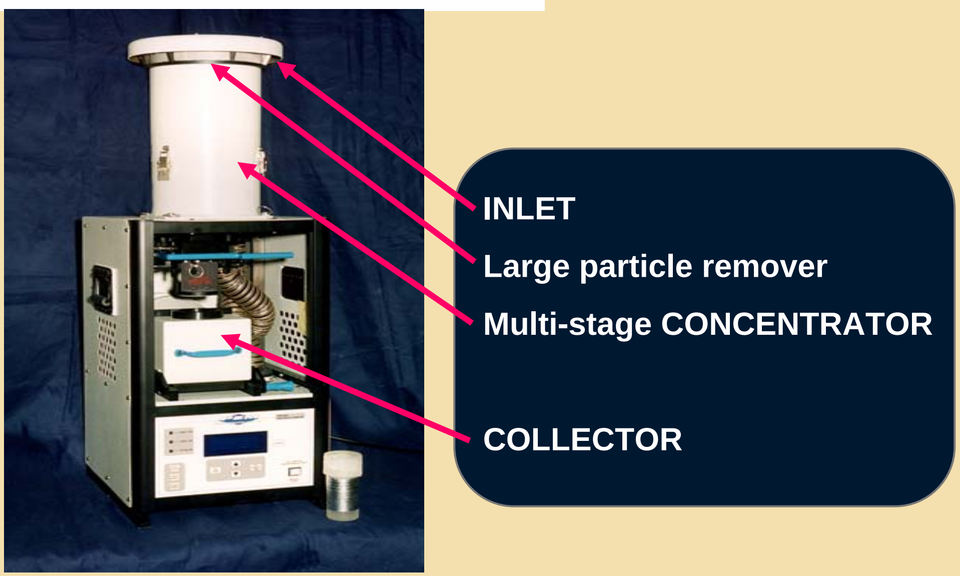


Example Biodetection Systems

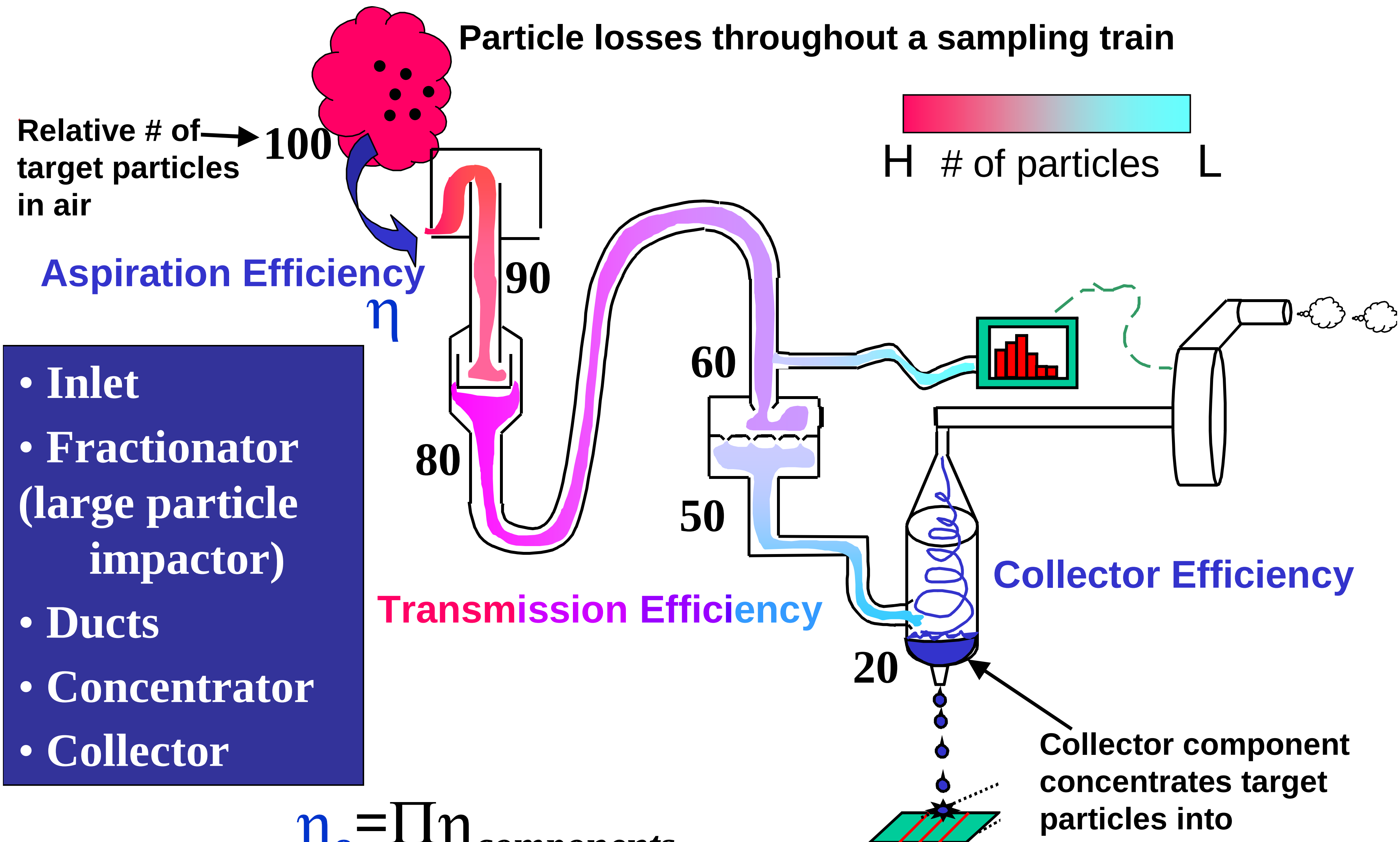
Trigger Inlets & Collector Inlets

BIDS

JBPDS



Typical Aerosol Sampling System

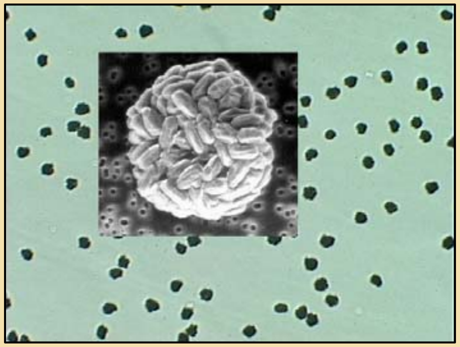


- Inlet
- Fractionator (large particle impactor)
- Ducts
- Concentrator
- Collector

$$\eta_o = \Pi \eta_{components}$$

Aerosol Particle Behavior

- Settling
- Impaction



TAKE-HOME MESSAGE:

Aerosols are NOT gases.

Their inertia gives us a handle on them.

Their inertia can confound our efforts to transport them.

Material is sparsely distributed in space.

Particle Settling in Still Air

Time to settle 5 feet by unit density spheres

0.5 μm	1 μm	3 μm	10 μm	100 μm
41 hours	12 hours	1.5 hours	8.2 minutes	5.8 seconds

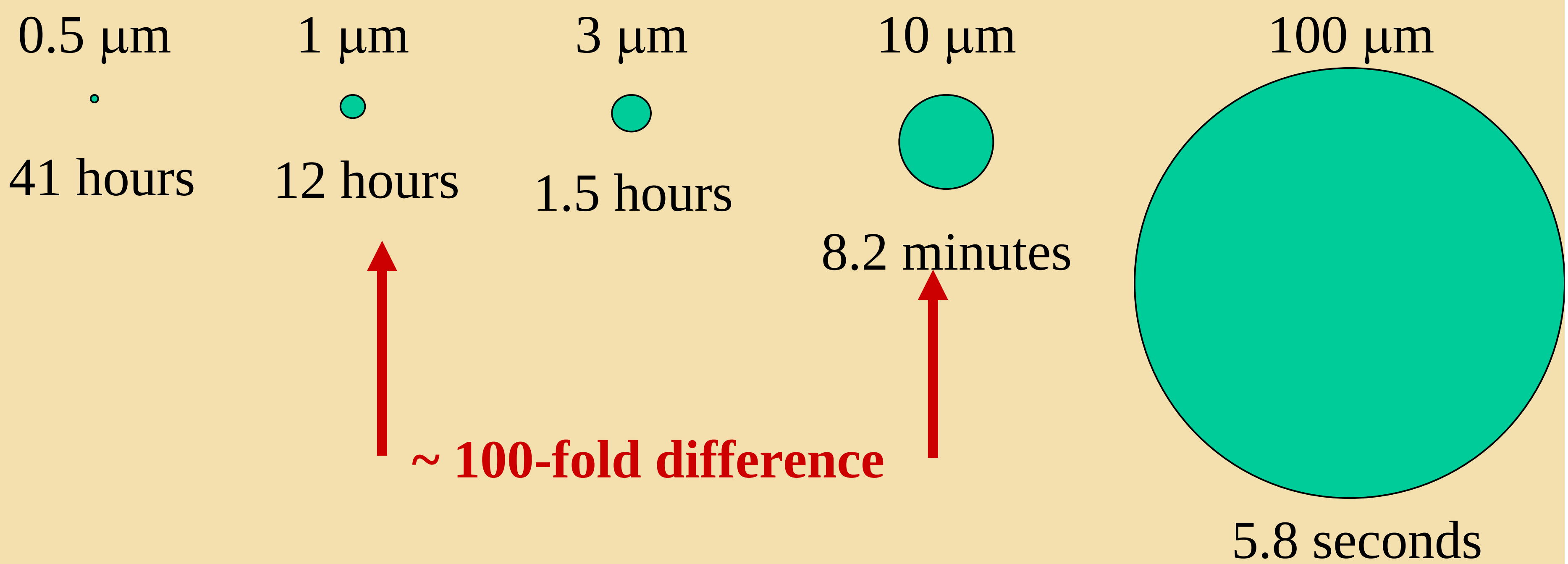
Aerodynamic diameter: diameter of unit density sphere that settles at the same velocity as particle in question

Sampling trains are usually vertical and avoid bends, horizontal.

- requires size dependent characterization over 1-10 micron.

Particle Settling in Still Air

Time to settle 5 feet by unit density spheres

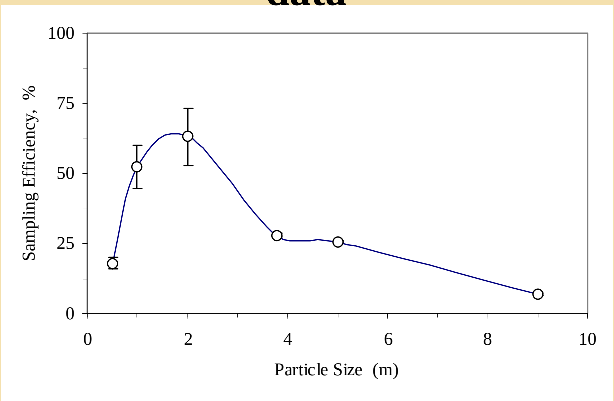


Both Large and Small Sizes are Difficult to Sample with High Efficiency

1 µm 3 µm 10 µm

Too little inertia – impactor concentrators and collectors require high acceleration

Typical sampler efficiency data



Too much inertia – difficult to aspirate and transmit through tubing to collector without wall losses

Aerosol Sampler Technology Challenges

Description

Provide advanced collectors and inlets

- smaller
- lighter
- less power
- inexpensive
- sub-freezing
- higher concentration liquid sample

Goals

- High efficiency inlets for 1-10 micron particles and wind speeds (stationary outdoors up to 15-20 mph, HVAC up to 25 mph, vehicles/ships maybe 60 mph?)
- High efficiency, low power aerosol concentrator for 1-10 micron particles
- Low temperature (range of US cities) aerosol collector for wet samples
- Dry aerosol collectors
- Triggered vs. Long term “sentinel” wet and dry aerosol collectors
- Viability-preserving aerosol collectors

Aerosol Sampler Performance Issues

- Detection Sensitivity (collected amount and concentration)
  - Air flow rate (sample size vs. time)
  - Collection Efficiency (particle size dependent – 1-10 micron)
  - Reject unwanted sizes, e.g., pollens
    - background suppression, dust
  - Concentration factor (into liquid or air)

- Utility
  - Rise time, Clear down time
  - Low & high temperature
    - wet collectors
    - dimensional stability, air viscosity
  - Clean up/Decon

- Logistics
  - Power consumption (incl. low temps)
  - Size & Weight (portability)
  - Liquid requirement (recirculating?)
  - Rugged, reliable, maintainable (lab devices unsuitable in field)

Bio Detection Systems

Aerosol Sampling Subsystem

Inlet

Fractionator

Aerosol Concentrator

Wet Collector

Dry Collector

SAMPLE

Vol
Conc

Size
Amount

Biological Analysis Subsystem

Optical Trigger

Immunoassay

PCR

Sample Prep

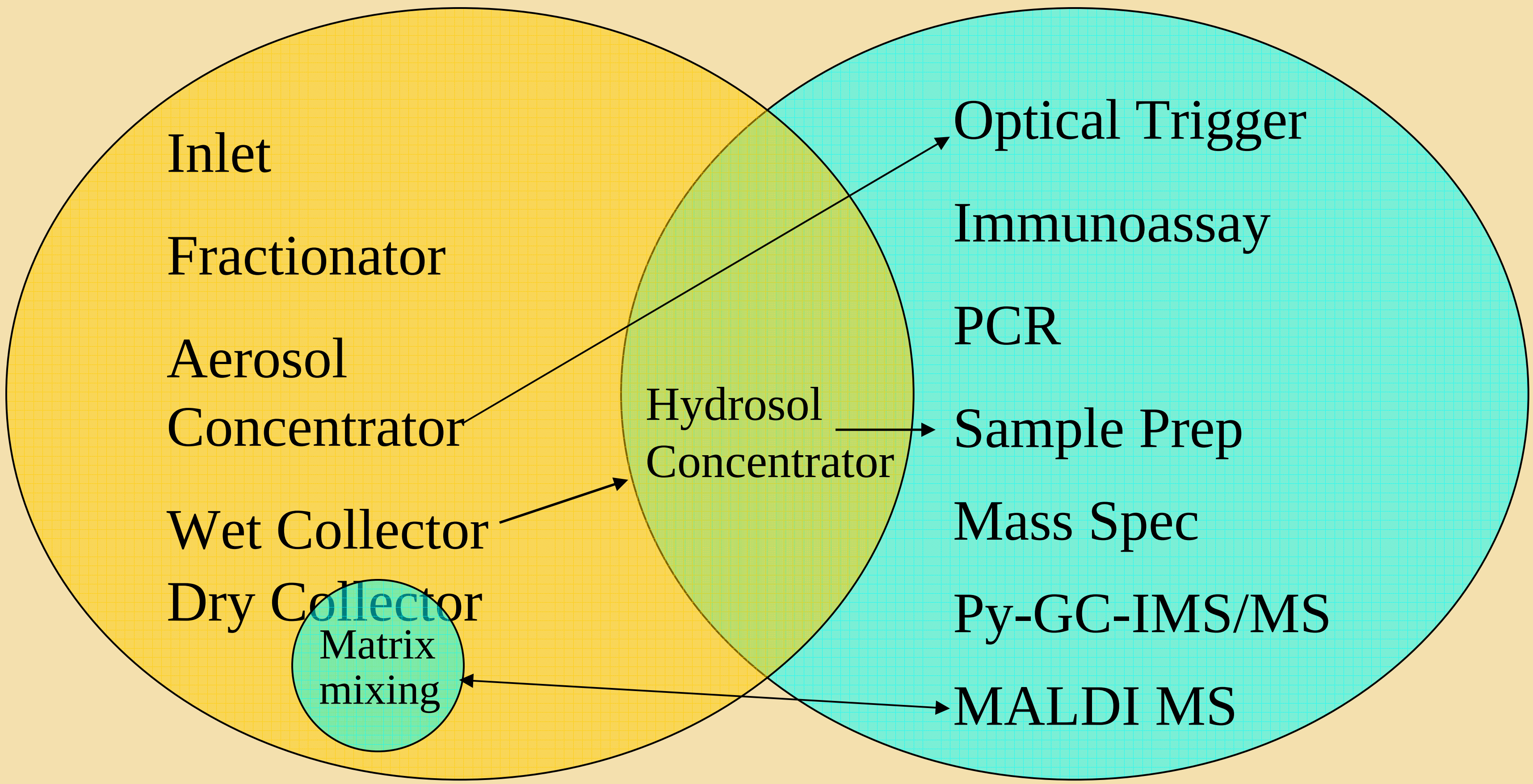
Mass Spec

Py-GC-IMS/MS

MALDI MS

Bio Detection Systems

Aerosol Sampling Subsystem **Biological Analysis Subsystems**



Advanced Aerosol Sampling Technologies

Conventional Inertial

Improved large particle rejection

Shrouded probes (for wind, moving platforms, or HVAC ducts)

Next Generation Inertial

Low power inertial concentrators

Low power, low temp wet collector

Non-inertial Technologies

Electrostatic concentrator/collector

Impeller collectors

Micro array dry collector

Hydrosol Concentrator

Acoustic concentrator

Power example

~500W **~150W** **<100W** **40 - 20W** **<10W**

FY04 Technology

Future Capabilities →

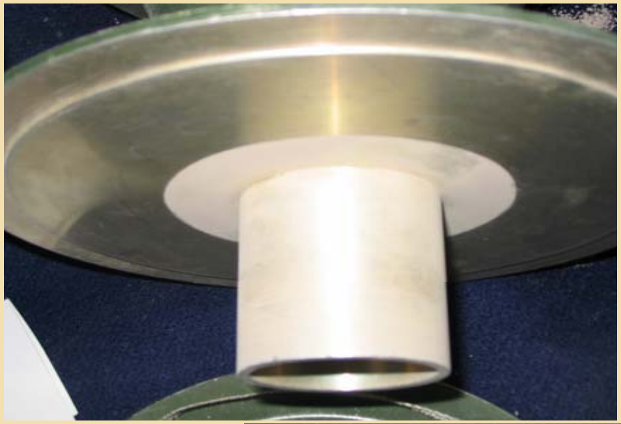
EXAMPLES OF

ADVANCED

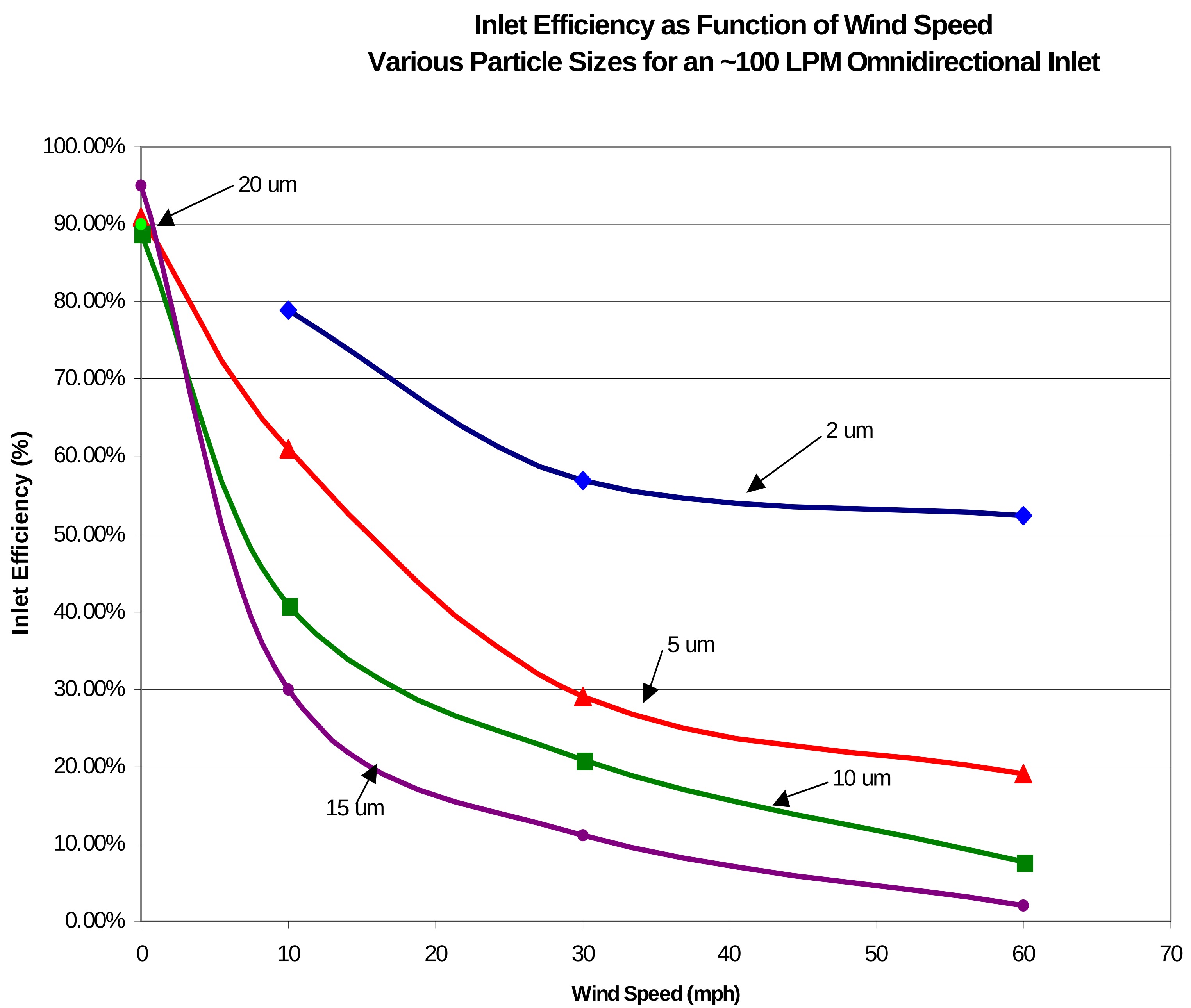
SAMPLING TECHNOLOGIES

CAVEAT: The following examples are given to illustrate each of the advanced aerosol sampling technologies currently being explored. This is not intended to be a complete catalog of all the applications of these technologies under development.

CONVENTIONAL INLET
heavy dust penetrates the fractionator

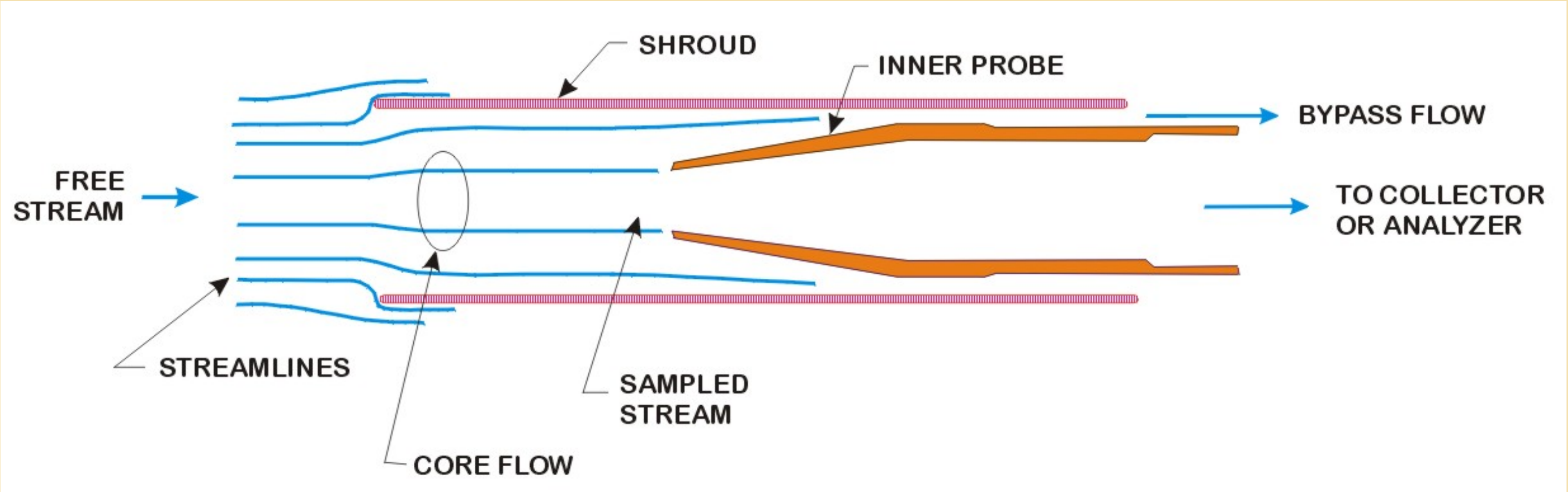


CONVENTIONAL INLET WITH OILED PAD
oiled pad improves fractionator for retaining large particles such as dust



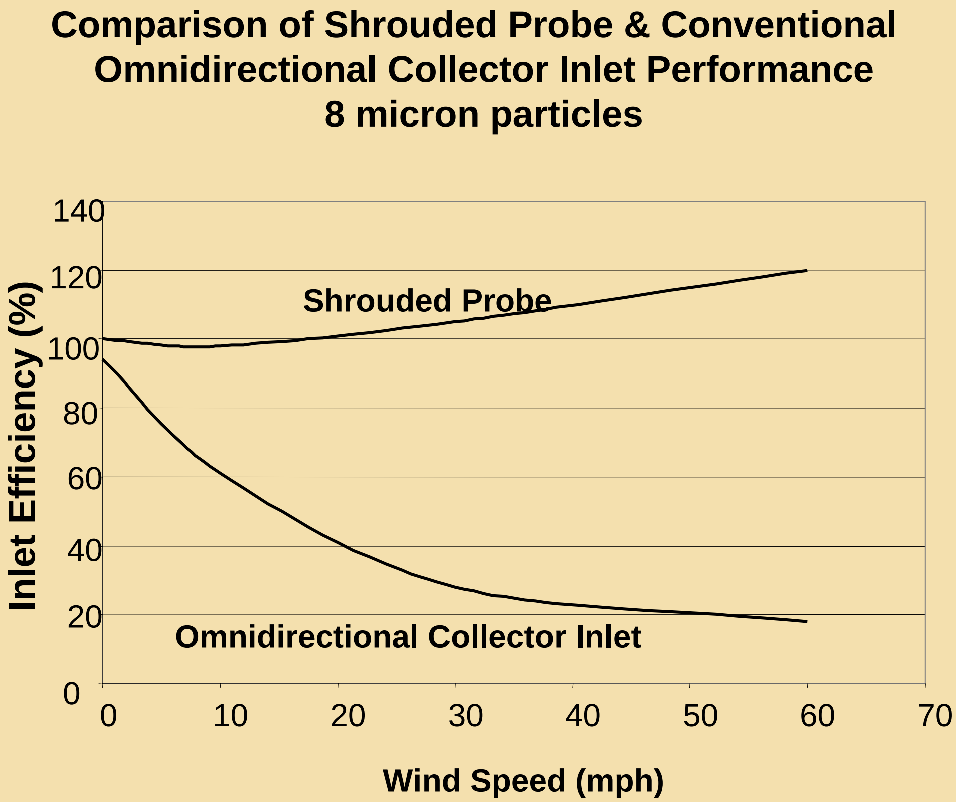
Inlet Efficiency as Function of Wind Speed
Various Particle Sizes for an ~100 LPM Omnidirectional Inlet
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Inlet Efficiency (%)
0
10
20
30
40
50
60
70
Wind Speed (mph)
20 um
2 um
5 um
10 um
15 um

SHROUDED PROBE INLET



Large Shrouded Probe Inlet

<u>**1,000 lpm Class Shrouded Probe**</u>

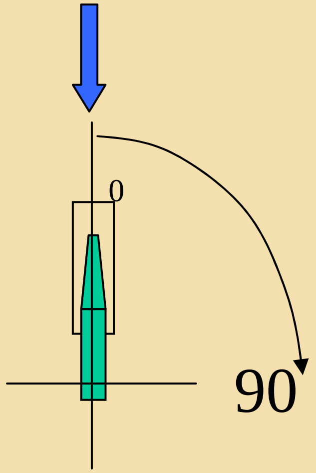


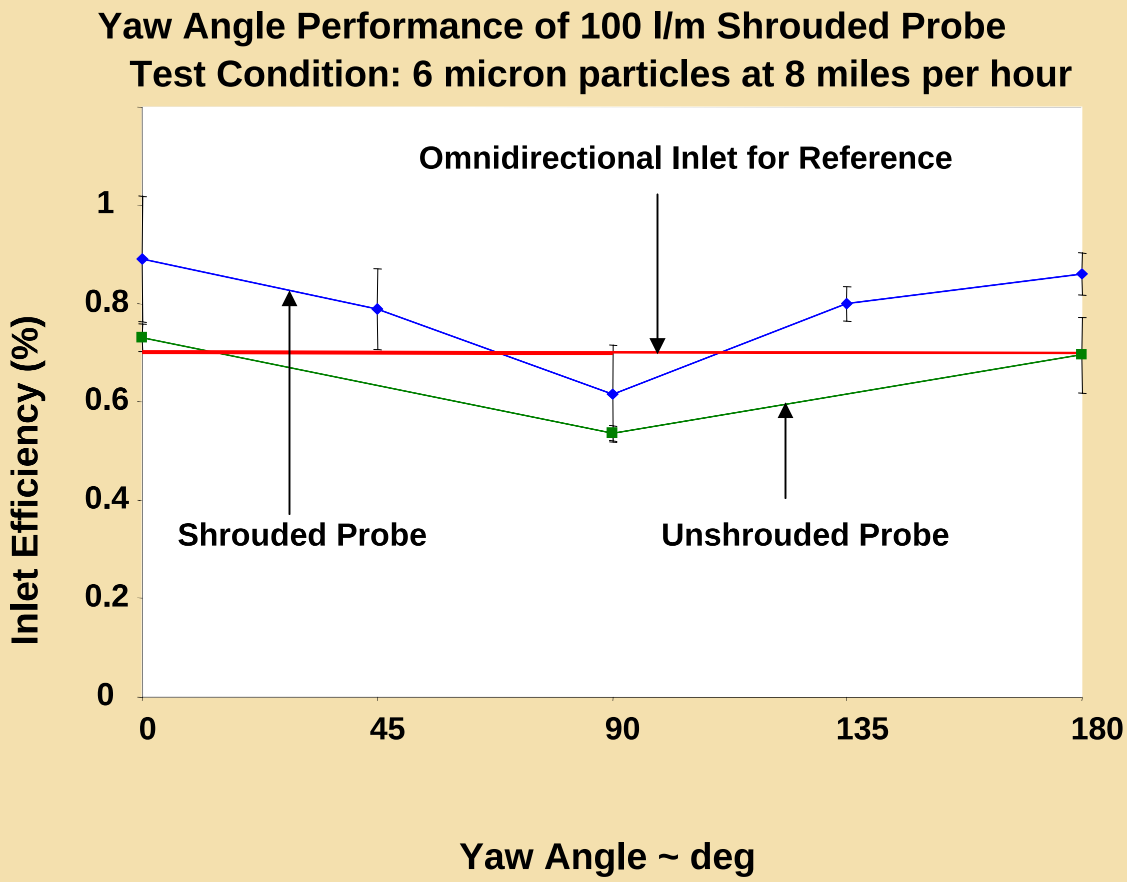
Shrouded Probe Inlet

•Shrouded probe inlet is superior at high wind conditions when pointing into wind, for example, in HVAC ducts.

•Yaw angle performance is good at low wind conditions. Sampling when wind is coming from side is not degraded considerably when compared with a simple omnidirectional inlet.

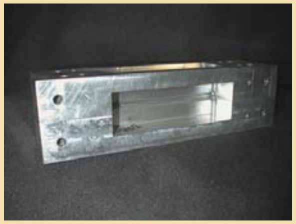
•Application: Shrouded Probe might replace omnidirectional inlets in outdoor situations and enhance windy and moving-platform performance without seriously degrading performance. (Full range of wind speeds and particles sizes remains to be studied.)





New Concentrators Under Testing

mini slits process small particles with low pressure drop

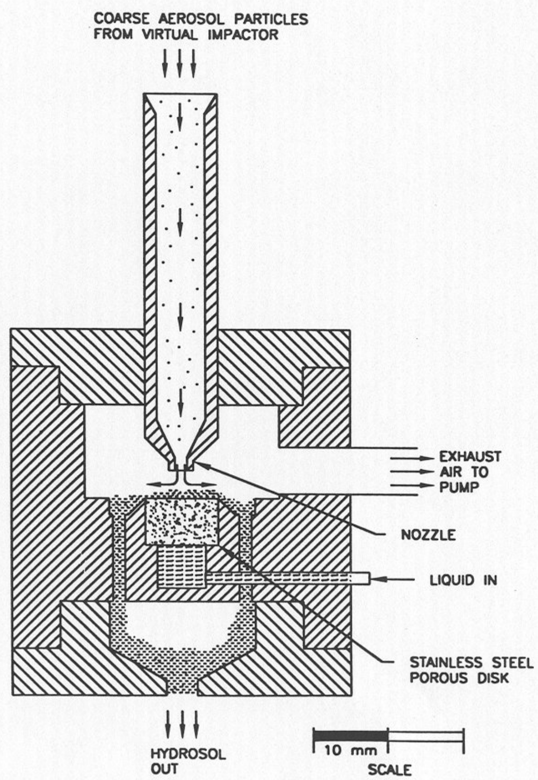


Test Bed for mini-slit design

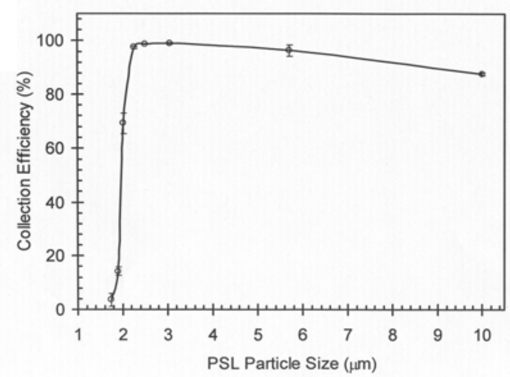
High flow (3,000+ lpm) Virtual Impactor Concentrator using a large horizontal array of mini-slits

New Aerosol Collector using mini-jets to capture small particles with low pressure drop

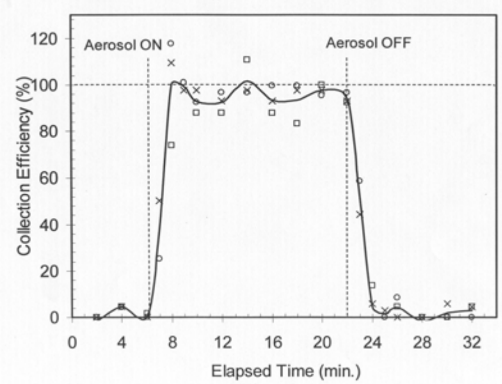
Energy Efficient
Low Temperature Wet Collector



Fractional Efficiency Curve



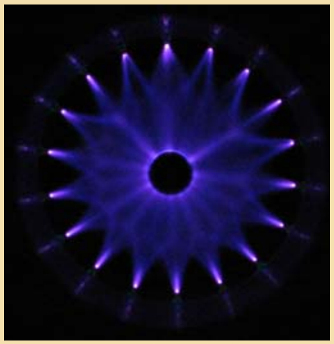
Response Time of the AHTS



MADE IN U.S.A.
GENERAL
ULTRA RULE
32NDS
MM

Electrostatic Collection

…versatile technology capable of interfacing to many detection systems…



AEROSOL

↓

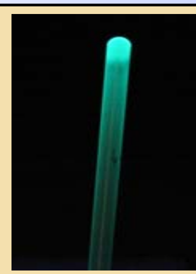
Corona-charging

↓

Electrostatic Focusing & Deposition

↓

Liquid

Wetted Column Collector	Self-cleaning Hydrophobic Membrane
	

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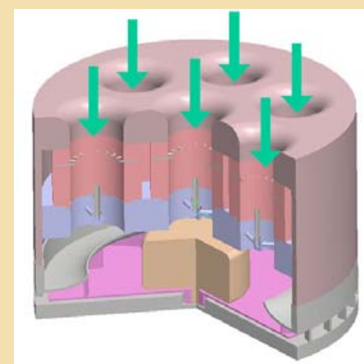
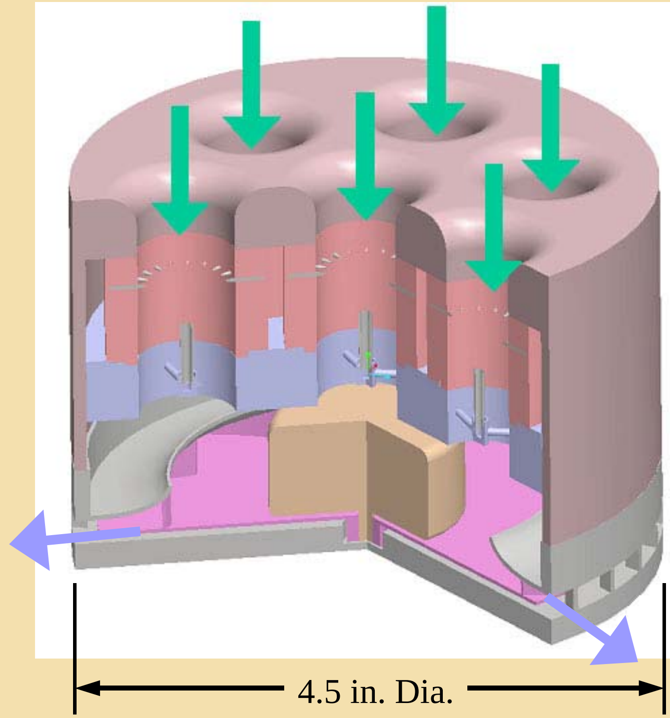
Assay or Antibody Detection System



Compact Electrostatic Aerosol Concentrator

...capabilities: compact, low power, high flow rate...

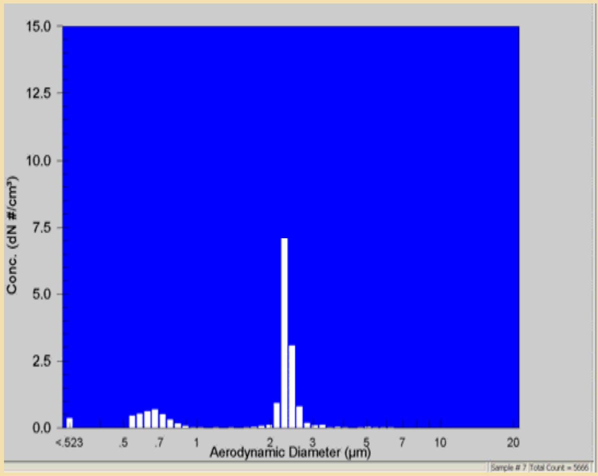
- **Direct aerosol concentration without energy consumptive inertial separation process upstream**
  - **Pressure drop orders of magnitude lower than inertial separation collector**
  - **Multi-unit samples >200 LPM with 1 watt fan**
- **Integrated high efficiency corona charger & collector for minimal size**
- **Particles deposited into small volume of liquid (< 1 ml)**
- **Low cost – low weight injection molded plastic construction**

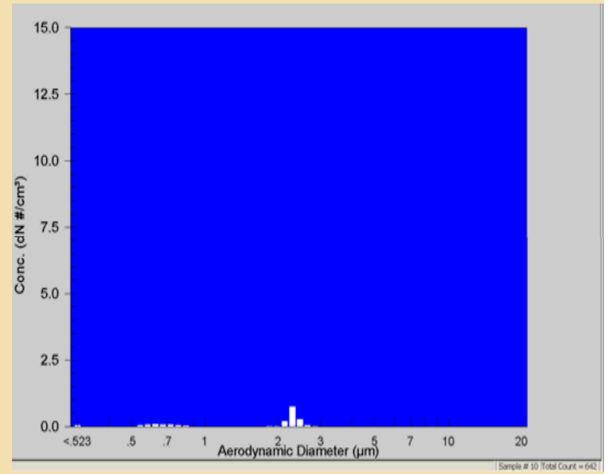


Electrostatic Radial Collector Performance

…original configuration vs. high density array data…

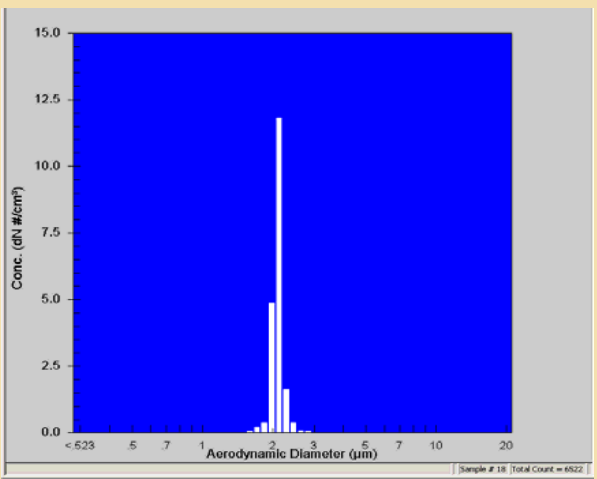
Electrostatic deposition of 2.3 µ beads onto a 0.125 in. diameter dry post from 0.75 in. diameter duct

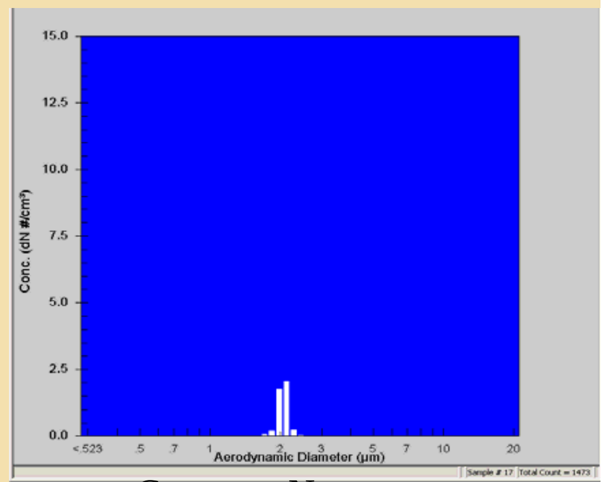




High Density Corona Array Collection Efficiency >85% @ 30 lpm

Electrostatics Off | **Electrostatics On**



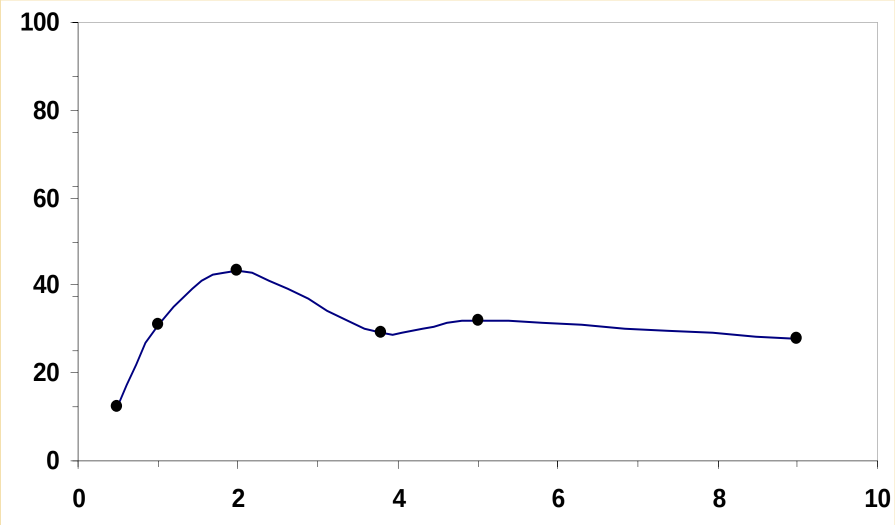


Original Configuration Corona Array Collection Efficiency >50% @ 30 lpm

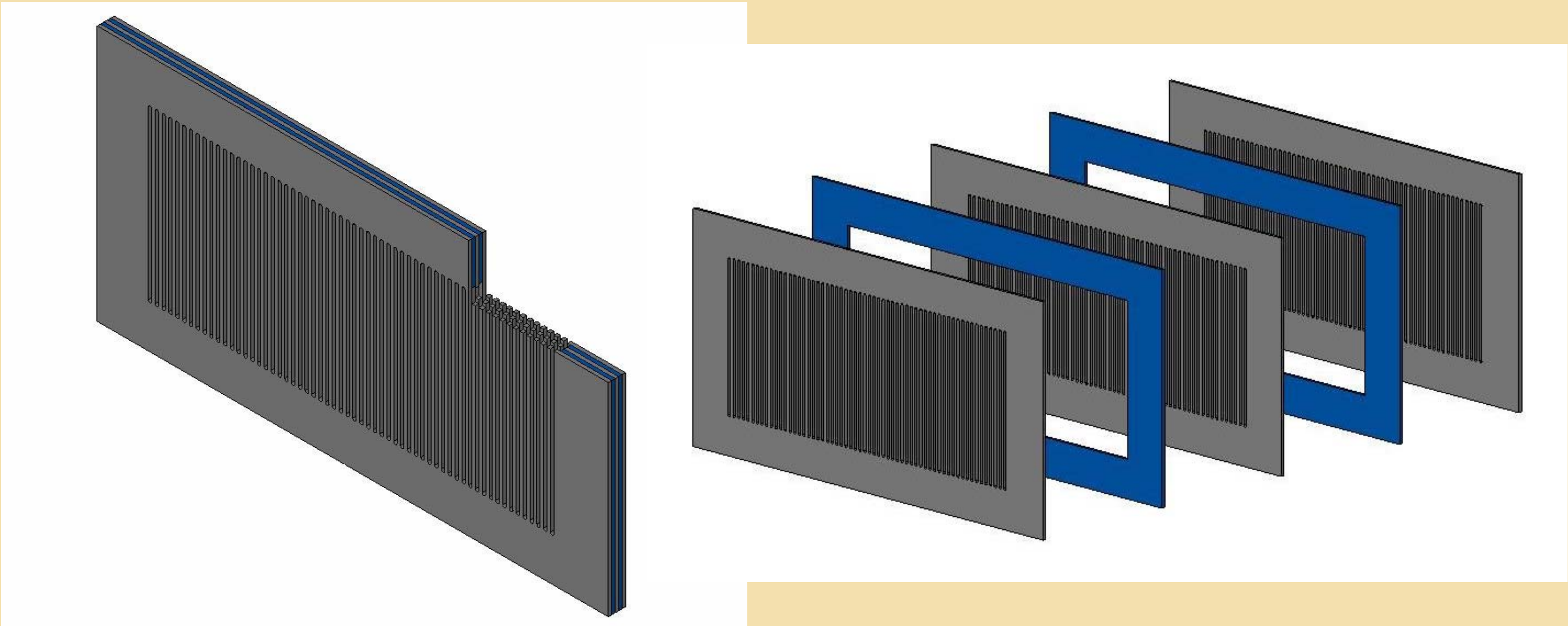
IMPELLER EXAMPLE

ROTATING ARM COLLECTOR

BioCapture Air Sampler



Micropillar Array Dry Collector



A low pressure drop, high flow filter with collection efficiency of a good aerosol collector (80-90%).

Particle Trajectories Through three rows of offset rectangular micropillars

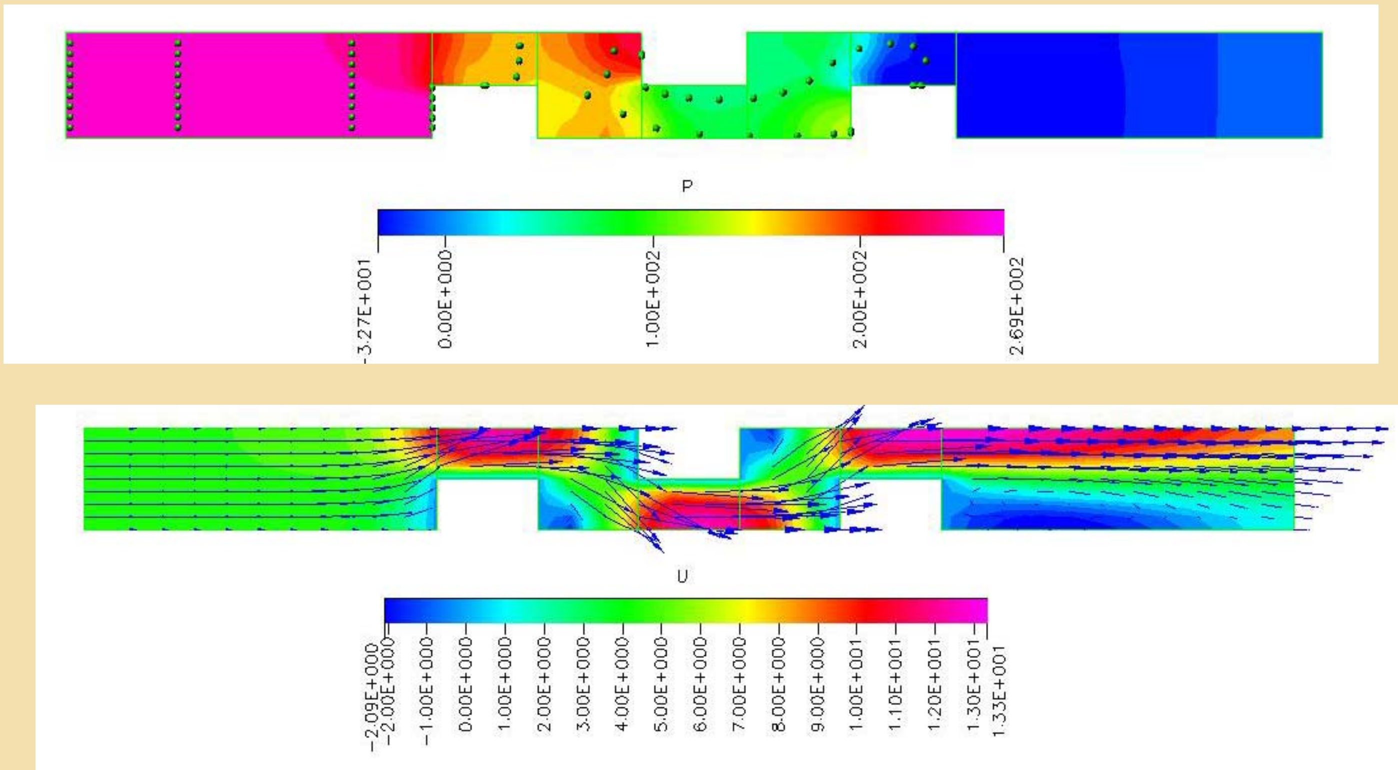
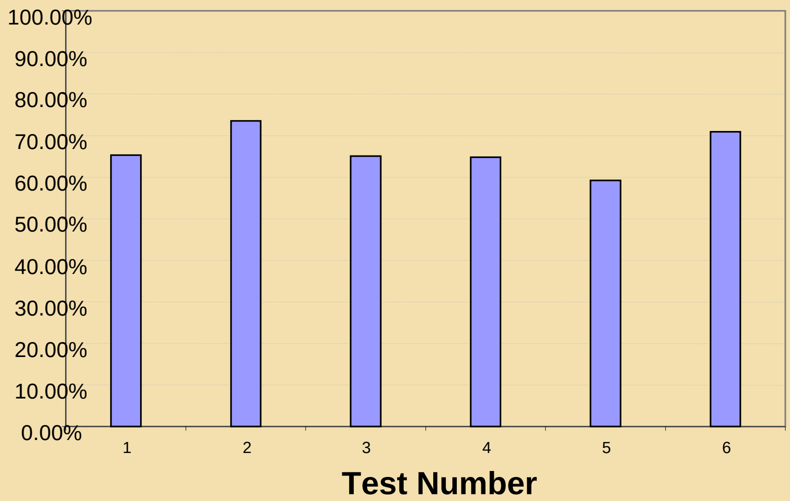
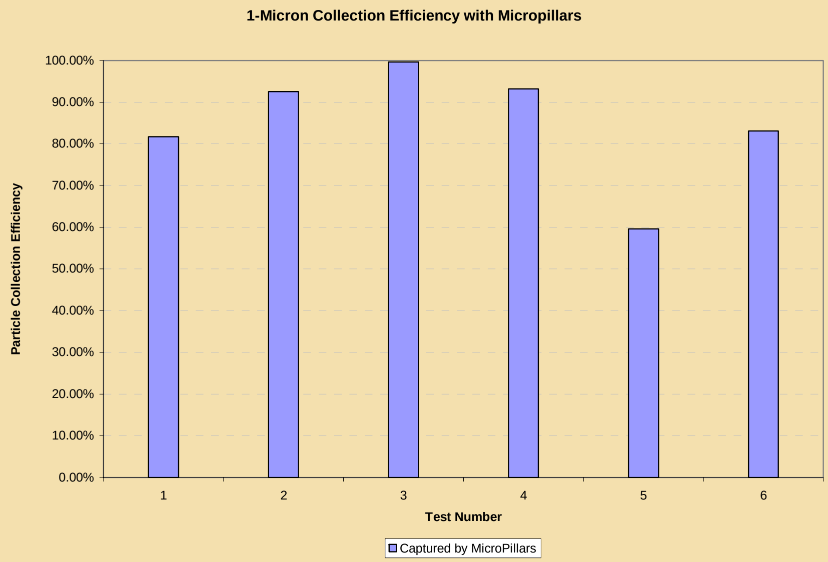


Figure 1. (a) Pressure Drop and droplet trajectories (b) Velocity Profile corresponding to an inlet velocity of 5 m/s and for particles of 1□m size with a 5V voltage potential.

Micropillar Results



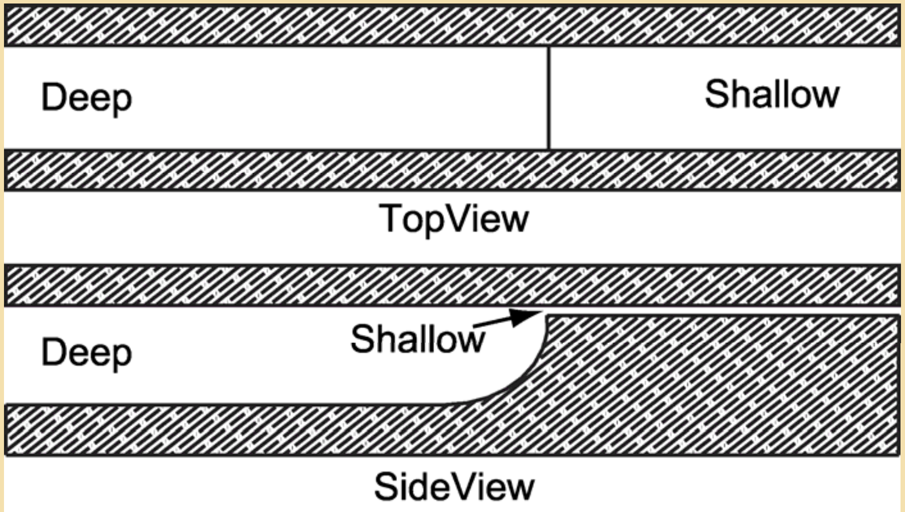


Aerosol Capture on **Uncoated** Micropillars at 1"Water Pressure Drop: 1-Micron PSL

Aerosol Capture on **Coated** Micropillars at 1"Water Pressure Drop: 1-Micron PSL

Example Hydrosol Concentrator

Two-Level Designs using dielectrophoresis (DEP)



UNIFORM FIELD DESIGN:

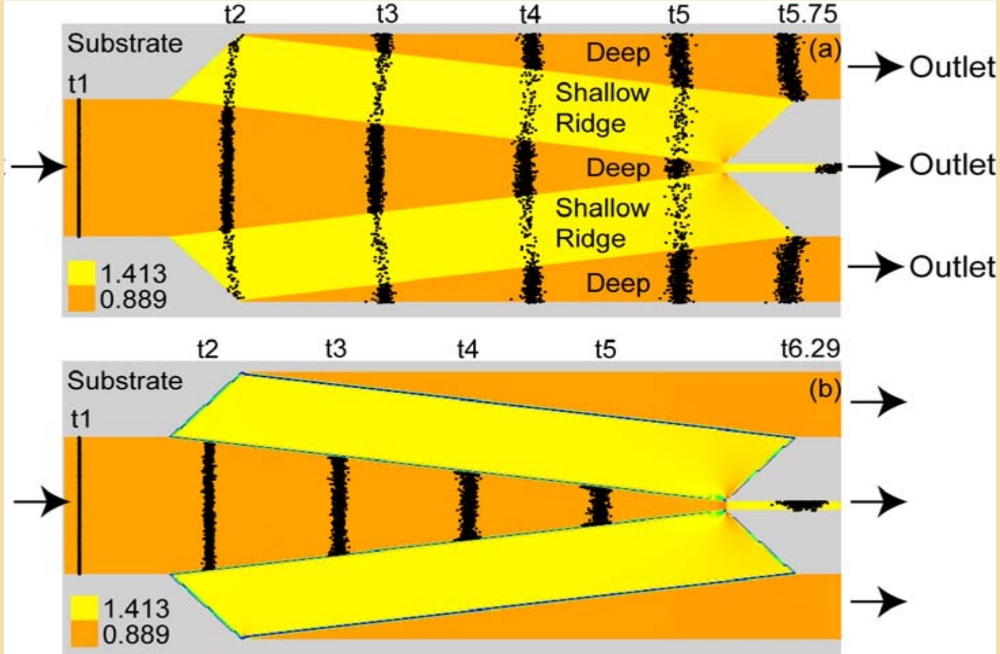
1) Electrochromatography: Dispersion Minimization

2) Particle Filtration: Bandwidth Minimization

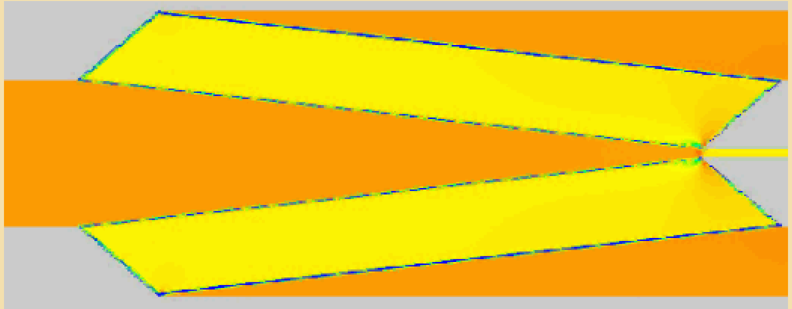
Simulation of particles sliding along ridge and out tube (forked splitter)

No DEP

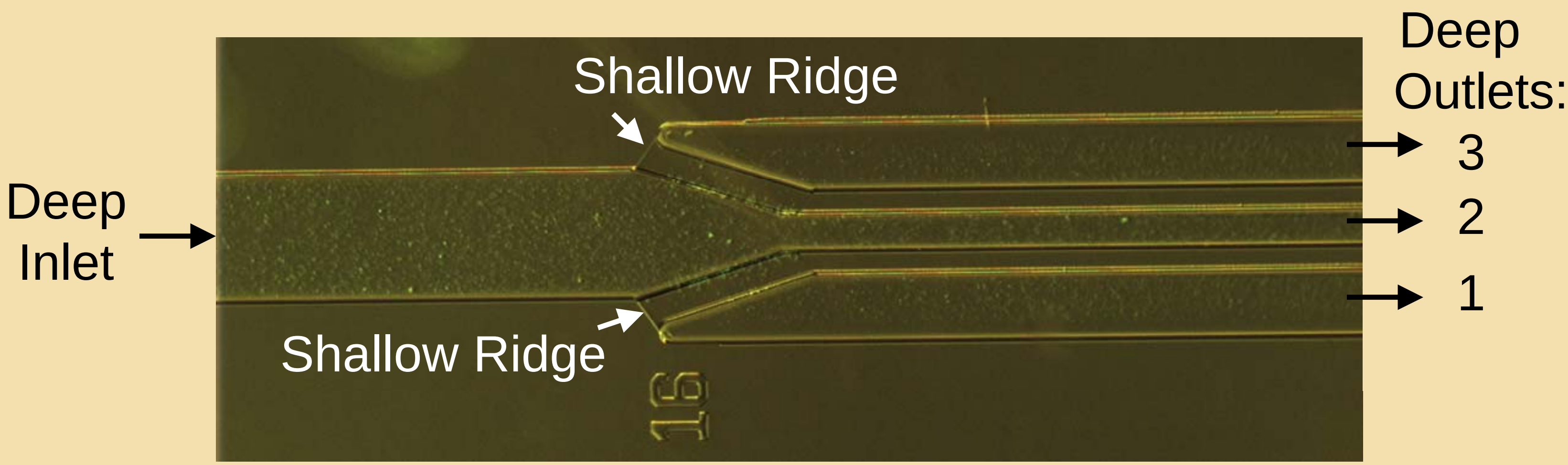
With DEP



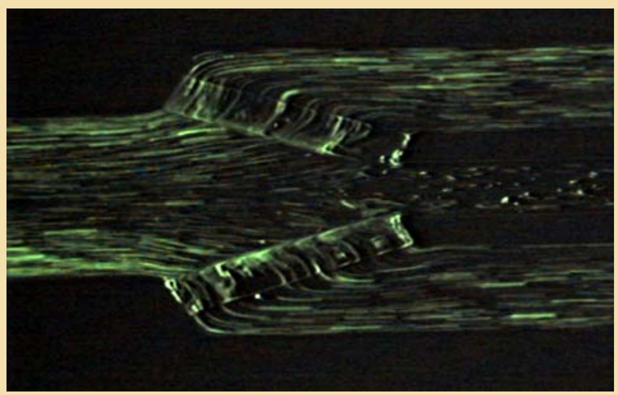
With DEP
(Animation)



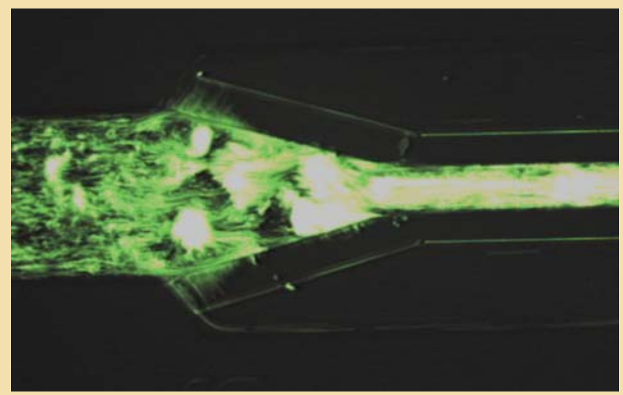
Forked Splitter Results
(Bacillus subtilis)



5 V



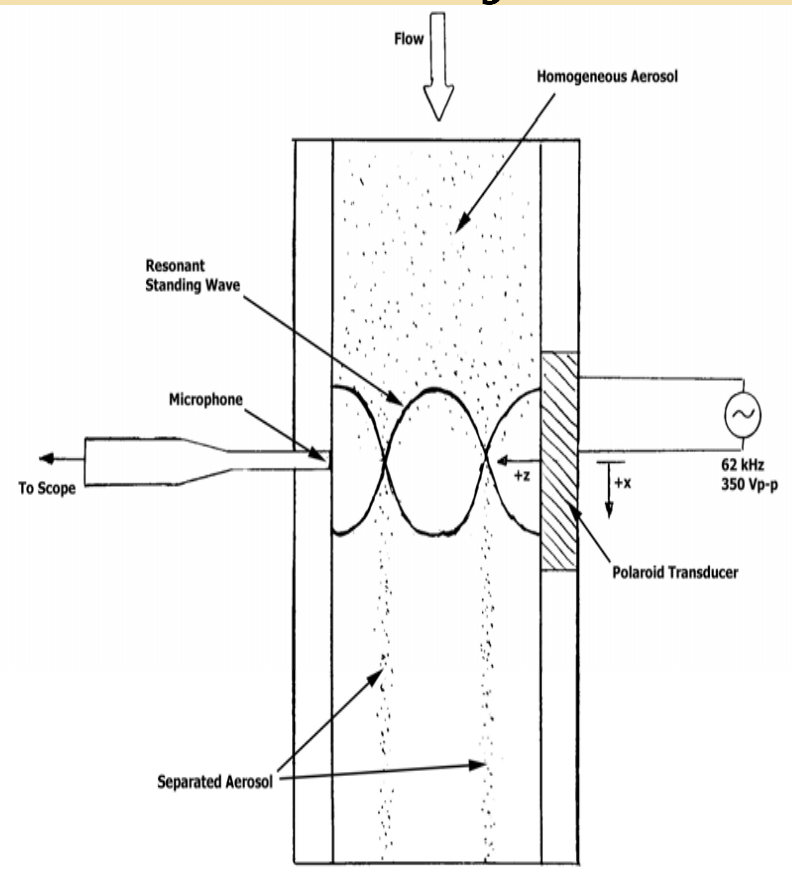
250 V



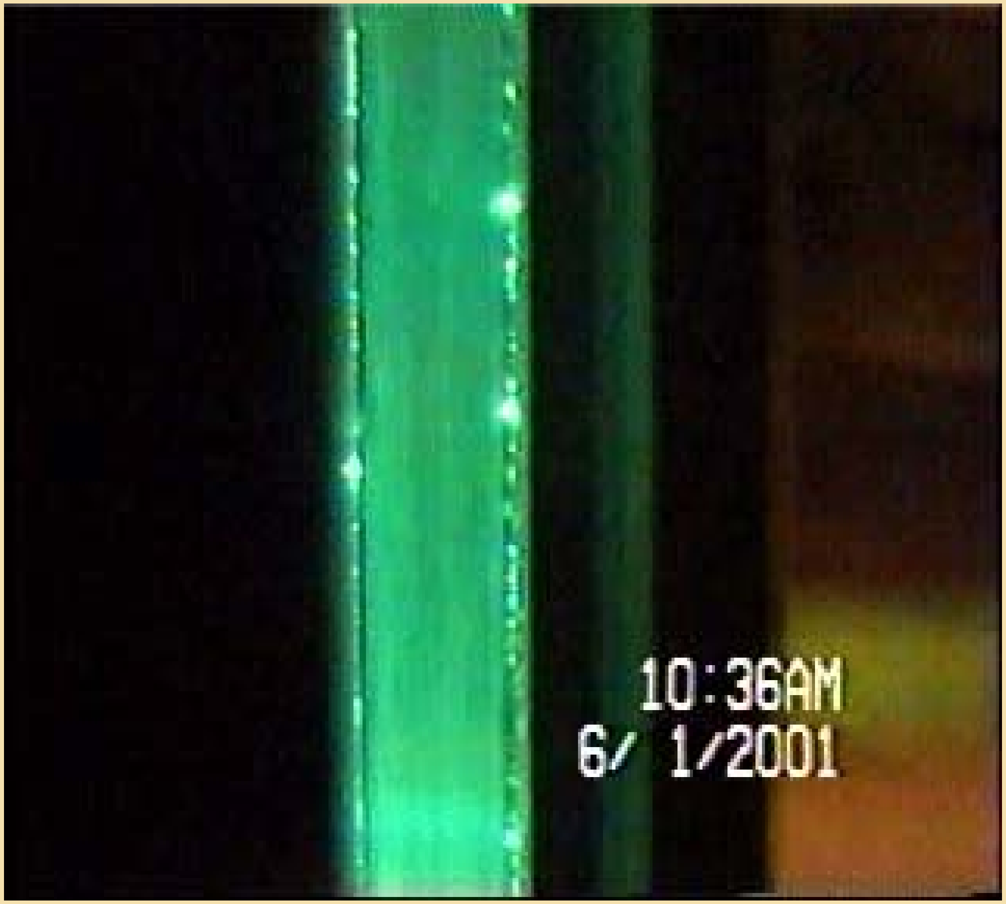
500 V

ACOUSTIC CONCENTRATION IN AEROSOL FLOW

Particle Trajectories



Video of Exit Flow



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